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Coherent Lidar Activities at NASA Langley Research Center

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Introduction

NASA Langley Research Center has been developing and using coherent lidar systems for many years. The current projects at LaRC are the Global Wind Observing Sounder (GWOS) mission preparation, the Laser Risk Reduction Program (LRRP), the Instrument Incubator Program (IIP) compact, rugged Doppler wind lidar project, the Autonomous precision Landing and Hazard detection and Avoidance Technology (ALHAT) project for lunar landing, and the Skywalker project to find and use thermals to extend UAV flight time. These five projects encompass coherent lidar technology development; characterization, validation, and calibration facilities; compact, rugged packaging; computer simulation; trade studies; data acquisition, processing, and display development; system demonstration; and space mission design. This paper will further discuss these activities at LaRC.

LRRP

The NASA LRRP[1] was started by NASA in FY02 after an external review panel recommended that NASA advance key laser and lidar technologies before the approval of a space mission, and also that NASA retain laser and lidar expertise in house[2]. LRRP is a joint LaRC-GSFC program and emphasizes development of 2- and 1-micron laser and lidar technologies, respectively. At LaRC the LRRP has been related to coherent lidar through work on a high-energy 2-micron pulsed laser[3], a high-PRF 2-micron pulses laser[4], the pump laser diode arrays (LDA) needed for 2-micron crystal lasers[5], and integrated 2-micron coherent-detection receivers[6]. For example, the development of a fully conductively-cooled 2-micron pulsed laser achieved first light in Jan. 2007 (see Figure 1).

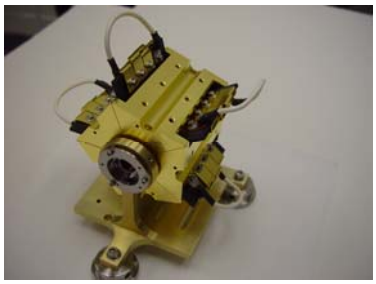

Figure 1. Fully Conductively Cooled Laser

A compact version of the laser transceiver was designed and fabricated and is currently being assembled (see Figure 4). The LDA Characterization Facility and Life Test Facility are continuously investigating commercially available and custom fabricated LDA's (see Figure 2). The LDA facilities are helping to overcome the challenge of achieving the LDA pulse lifetimes needed for space missions while running with 1 ms pulse times needed for the 2-micron laser. The LRRP is scheduled to continue through at least FY08.

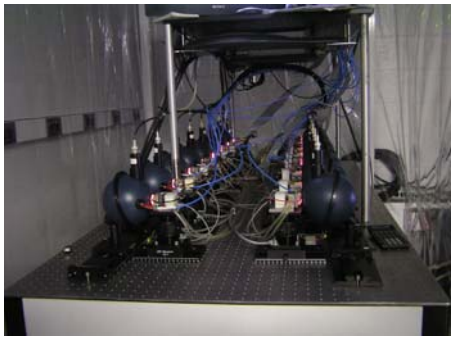

Figure 2. LaRC LDA Lifetime Facility

GWOS

The NRC released its first Earth Science Decadal Survey in Jan. 2007[7]. In anticipation of the report, NASA commissioned several space mission studies to design and cost the expected NRC recommendations. One of these studies was the Global Wind Observing System (GWOS) study utilizing both coherent-detection and direct-detection pulsed Doppler wind lidars in a "hybrid" approach to vertically profile horizontal wind vectors from space. LaRC participated with GSFC on this study and performed both an instrument design and a mission design[8]. An innovation adopted during the study was the shared use of four fixed telescopes by both lidar systems, thereby avoiding scanning for the first mission (see Figure 3).

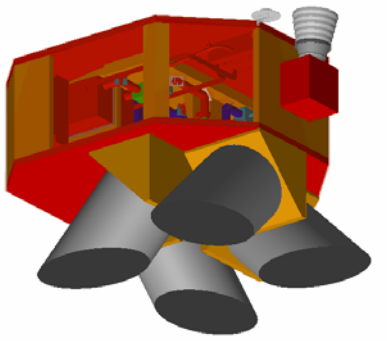

Figure 3. The GWOS four telescope design

During these studies LaRC personnel performed a major upgrade of the computer simulation of the wind measurement performance of coherent detection from space, and also used the improved simulation to perform coherent lidar and mission parameter trade studies. The trade studies continue to be refined.

IIP – Winds

LaRC is currently performing a 3-year Instrument Incubator Program (IIP) project funded by NASA SMD ESTO to take the state-of-the-art high-energy 2-micron laser technology developed at LaRC and to design and fabricate a compact, rugged version. This project is highly leveraging the knowledge gained in the LRRP efforts including the LRRP compact laser task (see Figure 4). Lessons learned from LRRP will be implemented to build an improved compact, rugged 2-micron coherent Doppler lidar transceiver. Although aircraft flight is not included in the project, we are attempting to build an aircraft-ready transceiver.

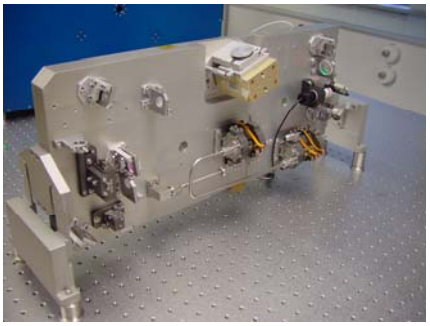

Figure 4. Compact Laser Transceiver

VALIDAR-LIF

LaRC has developed a mobile lidar testbed facility and a Lidar Intercomparison Facility (LIF)[9]. The mobile trailer facility is called VALIDAR (VALIDation LIDAR). VALIDAR has proved to be symbiotic with LRRP, the LRRP developed technology is tested in an atmospheric data collecting system environment, while questions about the atmosphere, the wind measurement technique, and the data processing are answered by using

the LRRP technology. The LIF is a unique facility that permits up to four Doppler wind lidars to be aimed parallel to each other while taking atmospheric data. The LIF permits closer examination of the wind measuring performance of Doppler lidars.

ALHAT

The NASA Autonomous precision Landing and Hazard detection and Avoidance Technology (ALHAT) program, begun in Feb. 2006, is part of NASA's Vision for Space Exploration (VSE). NASA needs to be able to place humans and cargo safely, precisely, and repeatedly on the lunar surface. Landing accuracies as good as <30 m 1 sigma are required in some cases. Hazards 30 cm and larger and slopes 5 degrees and greater must be detected and avoided. The ALHAT project will develop the new and unique hardware and software technologies necessary for these capabilities. LaRC is leading the sensor trades, design, development, and procurements. Lidar sensors are the leading choice for some of the required sensor suite. In particular coherent Doppler lidar is being considered for horizontal and vertical velocity sensing. LaRC is currently developing an all-fiber coherent detection altimeter/velocimeter lidar system for ALHAT evaluation.

Skywalker

Skywalker is a DARPA funded concept whereby UAVs take advantage of convective energy in the atmosphere (i.e., thermals) to gain altitude and to thereby extend mission duration and/or range without needing landings or fuel (see Figure 5). The project comprises several technologies with the primary one being a coherent-detection Doppler lidar to locate the available thermals. The lidar finds all nearby thermals and the UAV flies from one to the other to gain altitude.

Summary

There are many current activities related to the field of coherent-detection lidar at NASA LaRC. Table 1 connects the project names with the type of research activity at LaRC.

Acknowledgments

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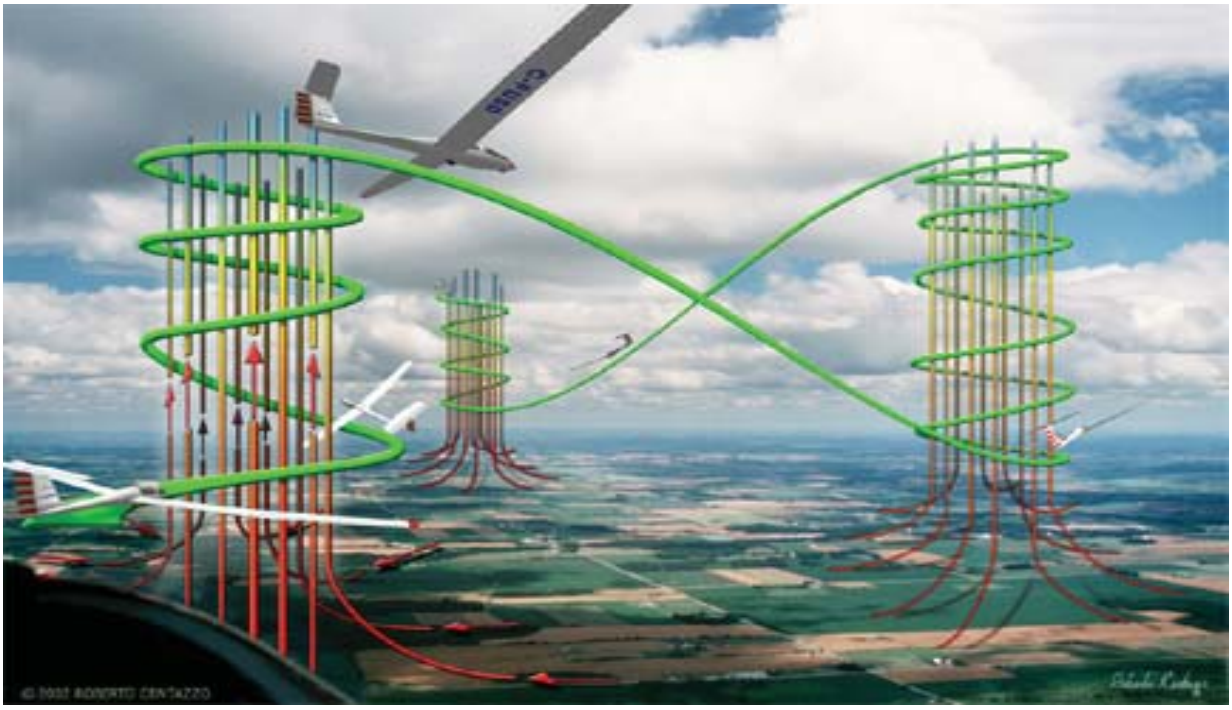

Figure 5. The Skywalker extend UAV mission concept

Table 1. Types of Research vs. NASA LaRC Projects

	LRRP	GWOS	IIP WINDS	VALIDAR & LIF	ALHAT	SKY-WALKER
Technology Development	✓				✓	✓
Characterization, Validation, Calibration Facilities	✓			✓	✓	
Compact, Rugged Packaging	✓		✓		✓	
Computer Performance Simulation		✓			✓	✓
Trade Studies		✓			✓	
Data Acquisition, Proc., and Display Develop.				✓		
System Demonstration			✓	✓	✓	✓
Space Mission Design		✓			✓	